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TECHNICAL REPORT ECOM 02391-F

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DEVELOPMENT OF CARBON ZINC BATTERIES

CAPABLE OF STORAGE UP TO 160°F

Final Report

by

TERRY G. MESSING

June 1967

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ECOM

UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

CONTRACT NO. DA 28043 AMC 02391 (E)

BURGESS BATTERY COMPANY

DIVISION OF SERVEL, INC.

FREEPORT, ILLINOIS 61032

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TECHNICAL REPORT ECOM 02391-F June 1967

DEVELOPMENT OF C/ZN BATTERIES CAPABLE OF STORAGE UP TO 160°F

Final Report

1 July 1966 to 31 March 1967

Report No. 2

Contract No. DA-28-043-AMC-02391 (E)

Project No. 1C622001A053, Task 02, Subtask 56

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Abstract -- High Temperature Carbon/Zinc Development Contract Number DA28-043-AMC-02391 (E)

Discussion of the development of a carbon zinc battery capable of prolonged storage at high temperatures is given. A summary of the ability of the present product is submitted. An analysis of the merits of geometric considerations is given, and data presented to show the capabilities of various cell constructions.

Publications, Lectures, Reports, and Conferences

Publications: None

Reports: None

Lectures: None

Conferences:

1. 15 August, 1966, outlined the objectives for high temperature carbon zinc development, held at ECOM, Fort Monmouth, New Jersey. Attended by Donald B. Wood, John J. Murphy and H. L. Williams of the U. S. Army Electronic Command and Howard J. Strauss and Terry Messing of Burgess.

2. 12 December, 1966, outlined progress to date and objectives for the completion of the high temperature carbon zinc development, held at Burgess Battery Company, Freeport, Illinois. Attended by Donald B. Wood of the U. S. Army Electronic Command and Joseph J. Coleman, Howard J. Strauss, Milton E. Wilke, Lloyd W. Eaton, Timothy S. Hungate, Terry G. Messing, and Roger Woodworth of Burgess.

3. 1 February, 1967, outlined progress to date and objectives for the completion of the high temperature carbon zinc development, held at ECOM, Fort Monmouth, New Jersey. Attended by John J. Murphy, Donald B. Wood, and Harry L. Williams of the U. S. Army Electronic Command and Howard J. Strauss and Terry G. Messing of Burgess.

4. 14 March, 1967, outlined progress to date and objectives for the completion of the high temperature carbon zinc development, held at Burgess Battery Company, Freeport, Illinois. Attended by Donald B. Wood of the U. S. Army Electronic Command and Joseph J. Coleman, Howard J. Strauss, Milton E. Wilke, Lloyd W. Eaton, Terry G. Messing, and Roger M. Woodworth of Burgess.

Purpose:

To investigate certain constructional changes that would improve the performance of Carbon/NH_4Cl-$ZnCl_2$/Zinc cells and/or batteries after high temperature storage. These changes were required to be of a nature that would allow the resulting cell to be readily manufacturable.

Specifically, a Ba386/PRC-25 battery as specified in MIL-B-18/244A(EL), 13 February 1963 is to be used as the experimental battery. It is desired that a battery that will reliably give twenty-four hours service after four weeks storage at 160°F be developed.

Introduction:

The first effort in this contract was applied to determining the performance capability of the present product. Burgess Battery Company presently is supplying spun paste, carbon zinc Ba386/PRC-25 batteries in production under contract DAA-B05-67-C-2901.

I. Performance of Present Product

This Ba386/PRC-25 battery is composed of forty-four "BR" cells. Ten cells in series and four in parallel (40 cells) make up the fifteen volt A_2 section, and two cells in series and two in parallel (4 cells) make up the three volt A_1 section. These batteries are sealed with a standard asphalt sealing compound. As part of the production control these spun paste batteries are tested fresh, after storage for twelve months at 70°F and after storage for three months at 113°F. Some representative data from recent production testing is given in Table I and shown as part of Graph I. The capacities shown in hours are average results and are followed by the number of samples which were averaged.

Sample production Ba386/PRC-25 batteries were stored at 113°F and 130°F and discharged at regular intervals. Table II shows the data obtained. This was repeated with a second lot of batteries and the table shows the overall averages. These capacities are part of Graph I.

To obtain data at 145°F and 160°F with these batteries it was necessary to change the construction. The sealing, potting asphalt material used in the production battery becomes soft at these elevated temperatures. The batteries were potted instead in a special high melt asphalt from Witco (H-942). This material does a fair job of potting but leaves some voids in the battery. The data from these batteries is given in Table III and is part of Graph I.

Graph I then shows the performance of the presently produced Ba386/PRC-25 spun paste battery. The graph shows good capacity retention at 70°F at and beyond one year. It shows a rate of capacity loss that is accelerated by a rise in temperature at which the battery is stored. However, even at 145°F, storage for four weeks is possible. But there seems a break here and no useable capacity was found after one week of storage at 160°F.

II. Investigation of Cell Type

There are two general cell geometries in which the carbon/NH_4Cl-$ZnCl_2$/zinc cell is made in the industry today. One class is the flat cell, and the second is the round cell class of carbon zinc batteries. It was desirable to run tests on comparable flat cell and round cell batteries to determine if one or the other had any unique advantages. The units chosen were Burgess 2U6 which is the standard flat (wafer) cell nine volt transistor radio battery, and a round cell battery composed of six AAA cells in series.

Thus both the round cell and the wafer cell batteries were nominal nine volt batteries and had equal amounts of mix in them.

These batteries were put on the following test:

Load:	2 minute / 1[illegible] ohms	18 minute / 2000 ohms

The test was run to 1.0 volts per cell. This test approximates the current densities in the cathode collector part of the wafer "UT" cell to the current densities experienced in a wafer "F" Cell in a Ba386/PRC-25 battery. Thus these tests gave us a measure of the ability to retain capacity in a wafer version of the Ba386/PRC-25 but do not give a measure of capacity available.

The round cell lots were all built with a paper lined round cell instead of the spun paste round cells used in section I above. There were three different paper linings-separators used; one separator was paper coated on one side with starch, one was paper coated both sides with starch, and one was coated one side with methocel.

The wafer cell lots were built with two sets of variations. One in the wafer cell to make a connection from cell to cell a suspension of silver plated copper powder in wax (silver wax) is used by Burgess. Work prior to the contract indicated that this wax vehicle at elevated temperatures would dissolve or plasticize the conductive plastic current collector on the cathode. This caused a rise in the resistance of the conductive plastic and battery failure. A possible substitute is a silver plated copper powder suspension in a water solution of methocel. This silver paste, however, tends to corrode itself due to the water in it and may not be an entirely

satisfactory solution. Two, wafer batteries are standardly potted in wax to minimize water loss. At the elevated temperatures experienced in the testing of these batteries, the wax will flow out. Therefore, a test of other possible potting materials was initiated.

The requirements of a potting material that will provide batteries capable of high temperature storage are:

1. Moderate temperature during potting. This eliminated certain asphalts which melted at such a high temperature that the plastic film wrapping the wafer cell was drastically degraded during potting.

2. Low viscosity of the potting material. This eliminated certain plastic formulations which were too thick to flow into the battery properly.

3. Ability to withstand $160^{o}F$ storage. Wax was eliminated because it liquified. It may be possible that certain wax formulations can be held in the battery.

4. Low water vapor transmission. This is a combination property, in this case, since vapor transmission is measured by the weight loss of the battery and the amount of loss is due to the combination of the vapor transmission properties of the potting material and how completely the potting material fills the voids in the battery.

Noting these requirements, several possible potting materials were chosen for trial. The potting material was evaluated by potting nine volt 2U6 batteries with the potting material. The resultant batteries were tehn stored at $160^{o}F$ and weighed periodically to determine weight loss. This weight loss is felt to be an indication of the effectiveness of the potting

material. The materials evaluated were:

1. Wax (#2300 petroleum base)
2. Polyurethane (Spencer Kellogg XP1152 and D. I. Castor Oil)
3. Spar varnish (commercial grade)
4. P-250 (a Witco asphalt)
5. H-942 (a Witco asphalt)
6. Polyisobutylene (A low molecular weight sample, Standard Oil)
7. Furane (A two part plastic material from Furane Plastics)
8. Epolene (Eastman Chemicals Products, Inc.)

The weight loss of these batteries is shown in Graph IIA and IIB.

From this data polyurethane and wax were chosen as a potting material for batteries to be stored at high temperatures. Four groups of 2U6 batteries were built. One with silver wax and wax potting, one with silver wax and polyurethane potting, one with silver paste and wax potting and one with silver paste and polyurethane potting.

Table IVA, IVB, and IVC show capacities obtained with the round cells and Table VA, VB, and VC show capacities obtained with the wafer cells.

The wafer cell has been used as a low current device with a relatively high internal resistance. When it is used in a continuous and at a fairly high discharge rate, the wafer cell does not generally perform well. However, Burgess has developed a wafer version of the Ba386/PRC-25 which does perform satisfactorily. There are ways of overcoming this internal resistance. However, in this test the round cell shows a definite superiority in fresh discharge. Further, if the results are examined, it is evident that with methocel paper there may be useable service after storage at 160°F.

Storage at $160^{o}F$ has associated with it many problems. The foremost would probably be leakage control. The AAA cells tested above proved very prone to this type failure. Another problem that these cells showed was ballooning after storage at $160^{o}F$., i.e. the mix slug and paper separator maintained their original shape and gas pressure apparently caused the zinc to cold flow into a torpedo-like shape. This problem gives emphasis to the necessity of properly venting these cells as shall be seen a little later.

III. Wafer Ba386/PRC-25 Construction

Despite the consideration given in the last section, a small number of wafer Ba386/PRC-25 batteries were built. These were potted with the polyurethane material as described above and the data is presented in Table VI.

These batteries used a methocel paper separator. The wafer cell as these were built will lose water relatively rapidly and this would account for the capacity loss. The degree of capacity retention would indicate that the methocel paper separator will satisfactorily survive $160^{o}F$ storage.

Prior to the start of this contract a wafer version of the Ba386/PRC-25 was developed. This battery was stored at $113^{o}F$ and $130^{o}F$. Refer to Table VII, which shows the capacity of several experimental lots of these batteries.

The data shown in Tables VI and VII was averaged and shown on Graph III. This construction with methocel paper separator shows an extended shelf life, greater than that of the presently produced battery.

IV. BR Round Cell Ba386/PRC-25 construction.

The next units built were of the general configuration of the spun paste production battery (i.e. 44 BR cells). However, these cells were lined with methocel paper instead of using the spun paste liner. These units were constructed on the spun paste production equipment. The paper lined cell generally needs to be tamped harder in order to properly wet up the separator. The spun paste line on which these batteries were made did not have facilities for proper tamping since spun paste cells need only light tamping, and the paper lined cells did not get properly tamped. Refer to Table VIII to see the performance of this lot. The capacities are not meaningful because of the lack of proper tamping. But the maintenance of open circuit voltage (OCV) and short circuit current (flash) would indicate that the separator is compatible with the cathode at these temperatures.

V. A Round Cell Ba386/PRC-25 Construction

There are then two problems present, (1) the round cells we had used were prone to leakage and (2) the zinc can was expanding due to the gas pressure being generated in the cell. It was thought that these two problems might be solved by a special potting material. If a hard, inflexible material were used, the potting material would tend to keep the cans from expanding away from the mix. Then if potting material were to cover the cell tops this material would act as a second line of defense against leakage.

To further stop leakage, the cells in this battery were closed by the Burgess mechanical seal method. In this method a plastic washer is forced over the carbon rod to the position normally occupied by the asphalt seal in a conventional cell. The zinc can is then sized down, necked down such that

a seal between the carbon rod and the plastic washer, and between the zinc can and the plastic washer were assured. Then a steel ring is forced over the zinc can to prevent it from cold flowing and relaxing the seal of the plastic washer. This mechanical seal is shown in Figure I.

Four experimental lots were built with various potting and mix variations.

1. Mix with 100% electro ore with no chrome, methocel paper with mercury, potted entirely in Araldite 502 epoxy.

2. Mix with 100% electro ore with chrome, methocel paper with no mercury, potted to shoulder of cell with Araldite 502 epoxy and cell tops with H942 asphalt.

3. Mix with 100% electro ore with chrome, methocel paper with no mercury, dipped in Araldite 502 epoxy and potted with H942 asphalt.

4. Mix with 100% electro ore with chrome, methocel paper with mercury, potted to shoulder of cell with Araldite 502 epoxy and cell tops with H942 asphalt.

The lot numbers used above are used as a cell description in Table IX.

The data is presented for the above batteries in Table IX. In all cases the potting procedure did put at least a thin coating of the epoxy over the entire surface of the cell. This epoxy material when it set up became very hard. The heat of storage caused slight expansion of the cells which caused the epoxy blocks to split. This splitting caused extensive lead breakage, also the zinc cans were split and the mechanical seal was pulled out of the cell.

Therefore it seems the cell must be allowed to vent at a sufficiant rate to relieve the pressure caused by the gassing occurring during storage and that this venting rate is appreciable.

VI. Single "A" Round Cell

Also stored were single "A" cells with the mechanical seal. These cells therefore did not have a coating of potting material and were able to vent properly.

These cells after storage were discharged on a simulated test that would give a drain equivalent to the drain on the cells in the A_2 sections of the whole batteries of the previous section. Data for these cells is shown in Table X and Graph IV.

The lots would be described as follows:

1. Mix with 100% electro ore with no chrome, methocel paper with mercury, no pinhole.*

2. Identical to 1 except with pinholes.

3. Identical to 1 except stored at 70°F.

4. Mix with 100% electro ore with chrome, methocel paper with mercury, no pinhole.

5. Mix with 100% electro ore with chrome, methocel paper without mercury, no pinhole.

VII. Gassing of "D" Cells with Inhibitors

When carbon/zinc cells are stored, especially at elevated temperatures, a certain amount of action dissolving or corroding the zinc is inevitable.

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* A pinhole was placed in the plastic seals of some cells to relieve internal pressure.

This action on the zinc causes the available capacity of the cell to decrease. One of the products of this reaction is gas. The rate of the action on the zinc may be measured by the rate of gas evolution.

ECOM supplied four samples of inhibitors. These were supplied as 2% in sal ammoniac. Standard Burgess 2MC (starch coated paper lined D size) cells were made using this sal ammoniac. These cells were then put in a mineral oil bath at 130°F. and the gas evolved was collected over the mineral oil.

On graphs IV, V, VI, VII, and VIII the data found is presented for:

Graph No.	
V	Control cell.
VI	Emulsifier STH (General Aniline and Film)
VII	Armeen T (Armour Chemical Co.)
VIII	Victamine C (Stauffer Chemical Co.)
IX	Victamine D (Stauffer Chemical Co.)

VIII. Conclusions

The original purpose of this work was the development of a battery capable of storage at 160°F. There was no usable service available from the spun paste cell batteries after any period of storage at 160°F. Apparently the starch layer is not compatible with the mix at this temperature.

The wafer-flat cell has the possibility of development for this use but the round AAA cell shows a greater fresh capacity at these drains and is better suited to sealing. Nonetheless, the wafer batteries did show some possibility of development. Wafer cell batteries in Table VI showed

capacities of eighteen or nineteen hours after storage for one month at 160°F.

Data shown in Table VIII shows the necessity of a well tamped cell. But the fact that the open circuit voltage did not drastically decline indicates that the methocel-mix couple is stable at 160°F.

Data shown in Table IX indicates that although these cells need to be potted to limit water loss and to hold the cell's shape, this potting cannot drastically reduce the venting rate of the cell.

The data from the single cells showed capacity retention after one month at 160°F to be very good when compared to that seen previously. If such a cell construction were used with "BR" cell batteries, the capacity after one month at 160°F would be passing.

IX. Future Work

Although this is a final report, work with this aim will most certainly continue toward a battery as proposed in this contract. The work here has not fully defined such a battery, but it has indicated the areas of investigation which will be fruitful. First work with single cells should be followed. Such work eliminates problems related to the connecting of cells and many of the potting problems related to large cell blocks. Our single cell data indicates that with the development of perhaps a "BR" size, methocel paper lined, mechanically sealed cell a satisfactory cell might be developed. Second work related to the making of reliable connections between cells and satisfactory potting of cell blocks should be followed. The gassing rate should be measured for these cells so that the potting can be adjusted to allow proper venting.

Supplement to Report No. ECOM 02391(E) dated January 1967, for services under contract No. DA-28-043-AMC-02391(E)

Identification of Personnel

J. J. Coleman, Vice-President for Research and Engineering,
Age: 59

Education: B. S. Chemistry, University of Colorado, 1931
M. S. Physics, University of Colorado, 1934
Ph. D. Chemistry, University of Colorado, 1936

Dr. Coleman has more than 20 years of experience in the battery industry and many patents and papers to his credit.

H. J. Strauss, Director of Research and Development,
Age: 45

Education: B.Ch.E., College of the city of New York, 1942
M.S. Chemical Engineering, Columbia University, 1947
Ph.D. Chemical Engineering, Columbia University, 1949

Dr. Strauss has more than 15 years of very diversified battery experience, and a large number of articles and patents to his credit.

M. E. Wilke, Chief Engineer
Age: 48

Education: A. B. Chemistry, Ripon College, 1938
M. S. Chemistry, Texas A. & M. College, 1940

Mr. Wilke has more than 20 years of direct battery research and development work and has several papers and patents to his credit.

F. A. Poss, Laboratory Manager,
Age: 33

Education: B. S. Chemistry, Northern Illinois University, 1957

Mr. Poss has approximately 4 years of pertinent experience.

T. G. Messing, Project Engineer,
Age: 26

Education: B. S. Chemistry, University of Wisconsin at Stevens Point, 1962

Mr. Messing has more than 4 years of pertinent battery experience.

R. M. Woodworth, Project Engineer
Age: 25

Education: B. S. Chemistry, Aurora College, 1963
One year graduate work in Chemistry, Kansas State University

Mr. Woodworth has more than six months of pertinent battery experience.

Time Distribution:

J. J. Coleman - Attend weekly reviews of contract work.

H. J. Strauss - Attend weekly reviews of contract work.

M. E. Wilke - Attend weekly reviews of contract work.

T. A. Poss - 69 hours

T. G. Messing - 675 hours

R. M. Woodworth - 537 hours

TABLE I: Capacity of Spun Paste Ba386/PRC-25, Storage at 70°F and 113°F

Date of Mfg. Month	Year	Capacity Fresh (hrs)	Samples	Capacity after Three Months at 113°F (hrs)	Samples	Capacity after Twelve Months at 70°F (hrs)	Samples
January	1966	38.0	54	31.3	5	30.7	5
February	1966	39.0	43	30.9	5	31.8	5
March	1966	38.0	94	30.6	5	32.3	5
Average		38.2		30.9		31.6	

TABLE II: Capacity of Spun Paste Ba386/PRC-25, Storage at 113°F and 130°F

Age	Temperature	First Lot A_1	First Lot Samples	First Lot A_2	First Lot Samples	Second Lot A_1	Second Lot Samples	Second Lot A_2	Second Lot Samples	Average A_1	Average A_2
Fresh	—	58.9	3	38.6	3	59.8	2	36.3	2	59.4	37.5
1 wk	113°F	59.2	3	38.4	3	67.9	3	40.8	3	63.6	39.6
2 wk	113°F	61.8	3	36.6	3	66.7	3	40.4	3	64.3	38.5
3 wk	113°F	62.5	3	35.3	3	67.0	3	38.9	3	64.8	37.1
1 mon.	113°F	58.3	3	36.2	3	55.2	3	37.2	3	56.8	36.7
2 mon.	113°F	54.3	2	34.7	2	54.5	3	34.4	3	54.4	34.6
3 mon.	113°F	55.7	3	30.4	3	58.6	3	32.7	3	57.2	31.6
1 wk	130°F	57.1	3	31.6	3	57.7	3	34.4	3	57.4	33.0
2 wk	130°F	60.0	2	32.9	2	53.2	3	33.2	3	56.6	33.1
3 wk	130°F	54.1	3	31.4	3	63.1	3	32.8	3	58.6	32.1
1 mon.	130°F	45.4	3	31.4	3	48.1	3	30.3	3	46.8	30.9
2 mon.	130°F	47.8	3	26.6	2	48.9	3	28.7	3	48.4	27.7
3 mon.	130°F	[illegible]	3	25.5	2	40.9	3	26.2	3	42.0	25.9

TABLE III A: Capacity of Modified Spun Paste Ba386/PRC-25, Storage at 145°F and 160°F

Age	Temperature	A_1 Section Fresh OCV	A_1 Fresh Flash	A_1 Time of Test OCV	A_1 Time of Test Flash	A_1 Capacity	A_2 Section Fresh OCV	A_2 Fresh Flash	A_2 Time of Test OCV	A_2 Time of Test Flash	A_2 Capacity
Fresh	--	3.25	9.4	--	--	63.0	16.4	20.0	--	--	37.2
Fresh	--	3.25	9.8	--	--	59.3	16.4	19.8	--	--	36.3
1 wk	145°F	3.25	9.8	3.20	8.0	67.0	16.4	21.0	15.8	16.8	32.8
1 wk	145°F	3.25	10.0	3.20	8.2	63.7	16.4	20.4	15.8	16.0	32.8
2 wk	145°F	3.25	10.0	3.00	5.6	38.4	16.4	21.0	10.4	1.2	0.0
2 wk	145°F	3.25	10.0	3.00	6.0	43.9	16.4	19.8	12.0	1.6	0.0
3 wk	145°F	3.30	10.2	3.10	8.2	54.9	16.4	21.0	15.6	16.4	25.5
3 wk	145°F	3.30	10.8	3.10	7.8	40.1	16.2	19.8	15.4	15.0	25.6
4 wk	145°F	3.25	10.0	3.10	8.0	41.9	16.4	20.0	14.4	11.0	4.0
4 wk	145°F	3.25	10.0	3.00	8.0	46.8	16.4	20.0	15.4	14.0	27.0
4 wk	145°F	3.25	9.8	3.10	7.0	34.5	16.4	21.0	15.2	15.0	25.0
4 wk	145°F	3.25	9.6	3.10	8.0	49.7	16.4	21.0	15.4	16.0	27.9
1 wk	160°F	3.25	10.0	2.90	4.8	4.7	16.4	20.0	16.4	1.4	0.0
1 wk	160°F	3.25	9.6	2.90	6.0	33.5	16.4	19.8	15.2	9.8	5.7
2 wk	160°F	3.25	9.8	3.00	4.0	9.7	16.4	19.8	14.0	4.6	0.0

TABLE III B: Capacity of Modified Spun Paste Ba386/PRC-25, Storage at 145°F and 160°F

		A_1 Section					A_2 Section				
		Fresh		Time of Test		Capacity	Fresh		Time of Test		Capacity
Age	Temperature	CCV	Flash	OCV	Flash		OCV	Flash	OCV	Flash	
2 wk	160°F	3.25	9.6	2.90	5.6	22.7	16.4	19.8	14.6	11.6	16.1
3 wk	160°F	3.25	10.0	2.80	1.0	0.0	16.4	21.0	6.1	0.0	0.0
3 wk	160°F	3.25	10.2	2.70	3.0	0.0	16.4	19.4	11.6	1.0	0.0
4 wk	160°F	3.25	10.0	2.90	1.0	0.0	16.4	19.4	5.20	0.0	0.0
4 wk	160°F	3.25	10.0	2.90	3.0	0.0	16.4	21.0	10.2	0.0	0.0
4 wk	160°F	3.25	10.0	2.40	0.0	0.0	16.4	19.2	7.40	0.0	0.0
4 wk	160°F	3.25	10.0	2.90	0.0	0.0	16.4	21.0	11.2	0.0	0.0

TABLE IV A: Capacity of Round Cell Test Batteries
(Six "AAA" cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wks.	1 Mon.	2 Mon.	3 Mon.
24077	Methocel paper one side; Mechanically Sealed Cell	8/22/66	70°F	38.3	34.3	31.7	37.3	36.0	35.6
				38.7	36.0	36.3	34.0	34.3	---
				37.7					
				33.0					
			113°F		37.0	36.4	36.0	35.5	0.0
					36.0	0.0	35.0	37.0	34.7
			130°F		37.0	35.0	37.7	--	32.0
					38.3	36.8	--	--	--
			145°F		36.0	29.3	31.0	--	0.0
					31.1	29.3	31.0	--	0.0
			160°F		21.6	0.0	26.3	0.0	21.3
					31.7	0.0	2.7	0.0	14.8
					27.2	0.0	2[illegible].3	0.0	16.8
					36.0	0.0	0.0	0.0	0.0

*Hours to 1.0 volts per cell thru 133 ohms per battery for 2 minutes and 2800 ohms per battery for 18 minutes continuous cycle at 70°F.

TABLE IV B: Capacity of Round Cell Test Batteries
(Six "AAA" cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wks.	1 Mon.	2 Mon.	3 Mon.
24078	Starch paper coated both sides; Mechanically sealed cell	8/23/66	70°F.	35.2	34.5	35.0	26.0	32.0	19.9
				33.3	36.0	27.5	0.0	30.8	25.0
				34.0					
				32.5					
			113°F.		35.0	32.7	33.0	0.0	15.7
					34.0	31.4	33.0	0.0	16.0
			130°F.		32.9	28.0	20.8	25.1	Defective
					34.2	28.7	30.2	--	Tests
			145°F.		25.4	0.0	22.7	--	0.0
					28.1	0.0	10.7	--	0.0
			160°F.		42.4	12.0	6.7	0.0	0.0
					0.0	0.0	0.0	0.0	0.0
					0.7	0.0	0.2	0.0	0.0
					21.0	0.0	0.0	0.0	0.0

* Hours to 1.0 volts per cell thru 133 ohms per battery for 2 minutes and 2800 ohms per battery for 18 minutes continuous cycle at 70°F.

TABLE IV C: Capacity of Round Cell Test Batteries
(Six "AAA" cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wks.	1 Mon.	2 Mon.	3 Mon.
24079	Starch paper coated one side Mechanically sealed cell	8/23/66	70°F.	0.0	27.0	3.9	0.0	22.8	27.0
				21.1				26.7	
				30.7					
			113°F.		29.4	29.0	27.9	23.1	27.0
			130°F.		27.4	0.0	25.3	22.2	--
					27.4	0.0	25.2	17.0	--
			145°F.		19.8	0.0	17.4	--	0.0
					17.0	0.0	9.9	--	0.0
			160°F.		20.1	0.0	0.0	--	--
					18.9	0.0	0.0	--	--

* Hours to 1.0 volts per cell thru 133 ohms per battery for 2 minutes and 2800 ohms per battery for 18 minutes continuous cycle at 70°F.

TABLE V A: Capacity of Wafer Cell Test Batteries
(Six "UT" wafer cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wk.	1 Mon.	2 Mon.
24015	Wax potted, Silver Wax connections	6/29/66	70°F.	13.4	15.0	15.4	13.9	13.0
				13.8	12.4	11.2	11.0	11.0
				13.5	12.4	12.5	12.0	11.2
				13.7	13.7	12.9	14.3	14.6
			113°F.		12.6	15.5	12.0	9.9
					12.0	11.7	12.9	8.0
					12.9	13.2	14.4	8.0
					12.5	12.7	--	14.8
			130°F.		12.3	9.3	2.8	0.0
					12.6	10.2	2.4	6.1
					2.8	7.8	2.5	0.0
					--	--	11.5	0.0
24016	Polyurethane potted, silver wax connections	6/29/66	70°F.	14.3				
				17.0				
				16.0				
				14.8				

* Hours to 1.0 volts per cell thru 133 ohms per battery for 2 minutes and 2800 ohms per battery for 18 min. continuous cycle at 70°F.

TABLE V B: Capacity of Wafer Cell Test Batteries
(Six "UT" wafer cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wk.	1 Mon.	2 Mon.
24016	Continued		130°F.		13.7	11.0	4.4	0.0
					11.0	10.5	5.5	1.4
					11.4	10.0	7.7	0.0
					13.6	--	4.6	1.0
			160°F.		11.5	7.0	0.0	0.0
					8.5	5.0	0.0	0.0
					10.4	6.0	0.0	0.0
					9.6	3.0	0.0	0.0
24017	Wax potted Silver Paste Connections	6/29/66	70°F.	13.6	13.0	13.5	14.1	13.3
				12.7	12.0	13.2	12.5	9.0
				9.2	10.1	13.0	12.2	9.5
				9.3	12.3	12.7	12.0	--
			113°F.		10.4	12.9	7.6	10.3
					11.4	11.0	11.0	11.0
					12.7	12.5	10.0	6.0
					9.7	12.0	12.3	10.3

* Hours to 1.0 volts per cell thru 133 ohms per battery for 2 min. and 2800 ohms per battery for 18 min. continuous cycle at 70°F.

TABLE V C: Capacity of Wafer Cell Test Batteries
(Six "UT" wafer cells connected in series)

Lot	Description	Date Stored	Storage Temperature	Capacity* Fr.	1 Wk.	2 Wk.	1 Mon.	2 Mon.
24017	Continued		130°F.		13.7	9.0	6.2	7.4
					10.7	5.2	6.2	3.3
					12.0	12.4	2.9	4.8
					9.6	8.3	2.7	6.0
24018	Polyurethane potted, silver paste connections	6/29/66	70°F.	11.6				
				9.8				
				12.0				
				12.0				
			130°F.		0.0	4.5	4.1	3.0
					8.7	5.0	4.0	3.3
					12.0	7.5	6.4	0.0
					8.3	7.5	4.6	0.0
			160°F.		5.0	2.3	0.0	--
					0.0	8.3	0.0	--
					4.0	0.0	0.0	--
					2.5	2.0	0.0	--

* Hours to 1.0 volts per cell thru 133 ohms per battery for 2 minutes and 2800 ohms per battery for 18 minutes continuous cycle at 70°F.

TABLE VI: Capacity of Wafer BA-386/PRC-25, Storage at 160°F.

Battery	Section	Fresh		2 Wks. @ 160°F.		4 Wks. @ 160°F.		Capacity*
		OCV	Flash	OCV	Flash	OCV	Flash	
1	A_1	3.25	15.0	--	--	--	--	89.0 (Fresh)
	A_2	16.2	29.0	--	--	--	--	43.1 (Fresh)
2	A_1	3.25	16.0	3.20	11.5	3.00	12.0	37.7
	A_2	16.0	29.0	15.4	26.0	5.4	0.0	0.0
3	A_1	3.25	11.0	3.20	11.0	3.00	0.2	0.0
	A_2	16.0	29.0	15.7	25.5	15.1	6.0	0.0
4	A_1	3.25	13.0	3.20	12.0	3.00	12.0	57.7
	A_2	16.0	29.0	15.7	26.0	15.2	14.0	17.7
5	A_1	3.25	11.0	3.20	9.0	3.00	10.0	21.5
	A_2	16.0	29.0	15.7	26.0	15.4	22.0	18.8

* Capacity on standard BA-386/PRC-25 drain. First battery discharged fresh, remaining batteries discharged after four weeks at 160°F.

TABLE VII: Capacity of Wafer BA-386/PRC-25, Storage at 130°F. and 113°F.

Lot	Age	Temperature (°F.)	Capacity - A_2 Section	Capacity - A_1 Section
1	Fresh	--	43.7, 43.2	94.6, 89.0
1	1 mon.	113	17.3, 42.7	82.7, 82.8
1	2 mon.	113	41.4, 41.5	82.7, 77.9
1	3 mon.	113	43.1, 41.3	Defective test, 77.5
1	4 mon.	113	40.9, 34.4	68.0, 72.4
1	9 mon.	113	28.7, 33.7, 31.7	35.2, 33.7, 31.0
1	2 weeks	130	37.2, 42.2	86.7, 72.3
1	1 mon.	130	41.7, 39.0	82.4, 78.7
1	2 mon.	130	33.0, 32.0	67.8, 69.1
1	3 mon.	130	36.0, 36.0	57.7, 53.0
2	Fresh	-	48.4	84.6
2	3 mon.	113	37.3, 38.3	78.9, 91.5
2	6 mon.	113	33.2, 34.5	60.0, 55.0
2	2 weeks	130	42.6, 42.8	83.5, 82.0
2	1 mon.	130	41.3, 43.2	73.5, 90.1
2	2 mon.	130	37.0, 38.3	73.1, 79.2
2	3 mon.	130	28.7, 30.3	54.5, 65.3
2	6 mon.	130	18.8, 14.4, 20.5	15.5, 60.7, 47.7

TABLE VIIIA: Capacity of BR Round Cell BA-386/PRC-25, Storage at 145°F and 160°F

Age	Temperature (°F.)	A1 Section Fresh OCV	A1 Section Fresh Flash	A1 Section Time of Test OCV	A1 Section Time of Test Flash	A1 Section Capacity	A2 Section Fresh OCV	A2 Section Fresh Flash	A2 Section Time of Test OCV	A2 Section Time of Test Flash	A2 Section Capacity
Fresh	--	3.25	4.2	--	--	70.0	16.2	9.0	--	--	14.0
Fresh	--	[illegible]	4.0	--	--	69.2	16.2	8.0	--	--	12.9
1 week	145	3.30	4.4	4.20	4.6	9.6	16.4	8.0	6.60	4.9	0.0
1 week	145	3.30	3.8	3.20	3.0	21.6	16.0	10.0	15.8	9.0	7.7
2 week	145	3.30	5.0	3.20	4.0	62.5	16.4	9.0	16.1	7.0	10.4
2 week	145	3.20	5.0	3.20	4.0	54.7	16.4	9.8	16.1	7.6	14.3
3 week	145	3.30	4.6	3.20	2.4	51.7	16.4	9.0	16.0	6.0	4.7
3 week	145	3.30	3.0	3.20	2.0	0.0	16.3	8.2	16.0	5.2	5.4
4 week	145	3.30	4.6	3.20	[illegible]	41.0	16.4	9.0	16.0	6.0	4.0
4 week	145	3.30	3.8	3.20	3.0	25.0	16.4	8.0	16.0	6.0	5.3
1 week	160	3.20	4.2	3.20	3.8	55.4	16.2	8.8	16.1	8.0	5.3
1 week	160	3.25	4.0	3.20	3.4	1.2	16.2	8.0	16.1	6.2	0.0
2 week	160	3.20	3.6	3.20	2.0	31.7	16.4	[illegible]	16.0	4.0	2.0
2 week	160	3.20	3.6	3.20	2.6	35.4	16.4	8.[illegible]	12.6	.40	0.0
3 week	160	3.30	4.6	3.20	2.4	51.7	16.4	9.0	16.0	6.0	4.7
3 week	160	3.30	3.0	3.20	2.0	0.0	16.3	8.2	16.0	5.2	5.4
4 week	160	3.20	4.0	3.20	2.0	0.0	16.2	9.0	15.9	4.0	0.0

TABLE VIII B: Capacity of BR Round Cell BA-386/PRC-25, Storage at 145°F and 160°F

Age	Temperature (°F.)	A_1 Section					A_2 Section				
		Fresh		Time of Test		Capacity	Fresh		Time of Test		Capacity
		OCV	Flash	OCV	Flash		OCV	Flash	OCV	Flash	
4 week	160	3.20	4.8	3.20	2.0	0.0	16.2	8.0	15.9	3.0	0.0
4 week	160	3.20	4.0	3.20	1.0	0.0	16.2	8.8	15.9	2.0	0.0
4 week	160	3.20	4.2	3.20	1.0	0.0	16.2	8.8	15.8	2.0	0.0

TABLE IX: Capacity of "A" Round Cell Ba386/PRC-25 Batteries

Storage at 160°F

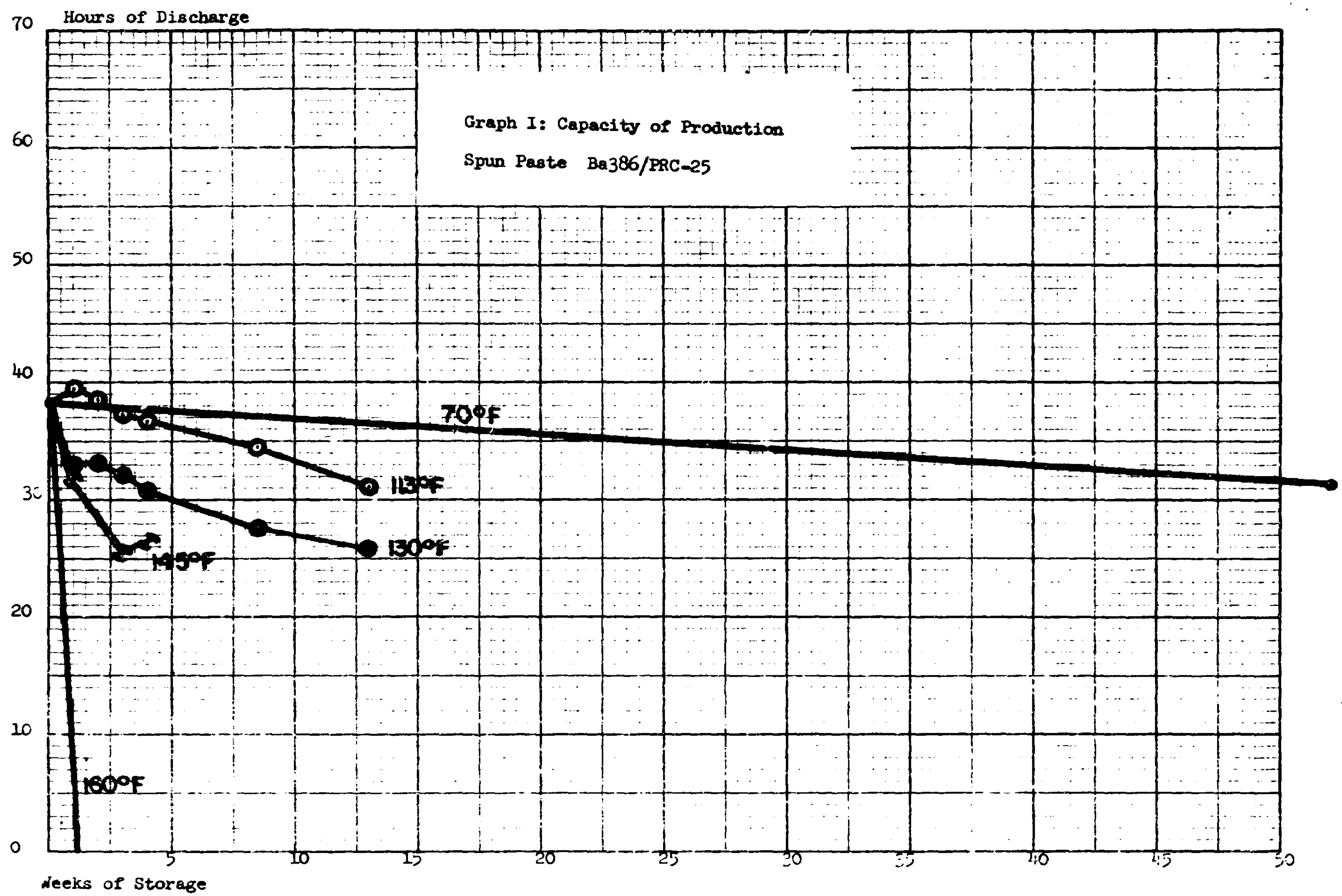
Lot	A_1 Section					A_2 Section				
	Fresh OCV	Fresh Flash	One Week OCV	One Week Flash	Capacity Fresh	Fresh OCV	Fresh Flash	One Week OCV	One Week Flash	Capacity Fresh
1	3.20	42.0	--	--	83.5	16.0	30.0	--	--	31.6
1	3.20	41.0	.10	0.0	--	16.0	28.0	1.40	.01	--
1	3.20	40.0	.06	0.0	--	16.0	29.0	.38	0.0	--
1	3.20	42.0	.10	0.0	--	16.0	29.0	.70	0.0	--
1	3.20	40.0	.18	0.0	--	16.0	28.0	.22	0.0	--
1	3.20	41.0	0.0	0.0	--	16.0	29.0	1.40	.05	--
1	3.20	41.0	.50	0.0	--	16.0	29.0	2.86	.80	--
1	3.20	41.0	2.64	2.8	--	16.0	29.0	2.90	.10	--
1	3.20	42.0	.10	0.0	--	16.0	30.0	1.34	0.0	--
1	2.80	25.0	0.0	0.0	--	15.8	25.0	4.10	.05	--
2	3.30	21.0	0.0	0.0	--	16.4	16.0	.26	0.0	--
2	3.30	23.0	.08	0.0	--	16.4	17.0	2.20	.05	--
2	3.30	16.0	0.0	0.0	--	16.4	8.0	4.20	.05	--
2	3.30	23.0	.80	.10	--	16.4	17.0	4.50	.05	--
3	3.30	23.0	1.50	.40	--	16.4	16.0	11.4	1.2	--
3	3.30	22.0	1.0	0.0	--	16.4	16.0	6.60	.60	--
3	3.30	22.0	.50	.20	--	16.4	16.0	10.0	1.4	--
3	3.30	23.0	.60	0.0	--	16.4	17.0	6.80	.40	--
4	3.30	22.0	0.0	0.0	--	16.4	17.0	0.0	0.0	--
4	3.00	22.0	0.0	0.0	--	16.2	17.0	2.90	1.2	--

TABLE X: Capacity of Single "A" Round Cells on a Ba386/PRC-25 A_2 Section

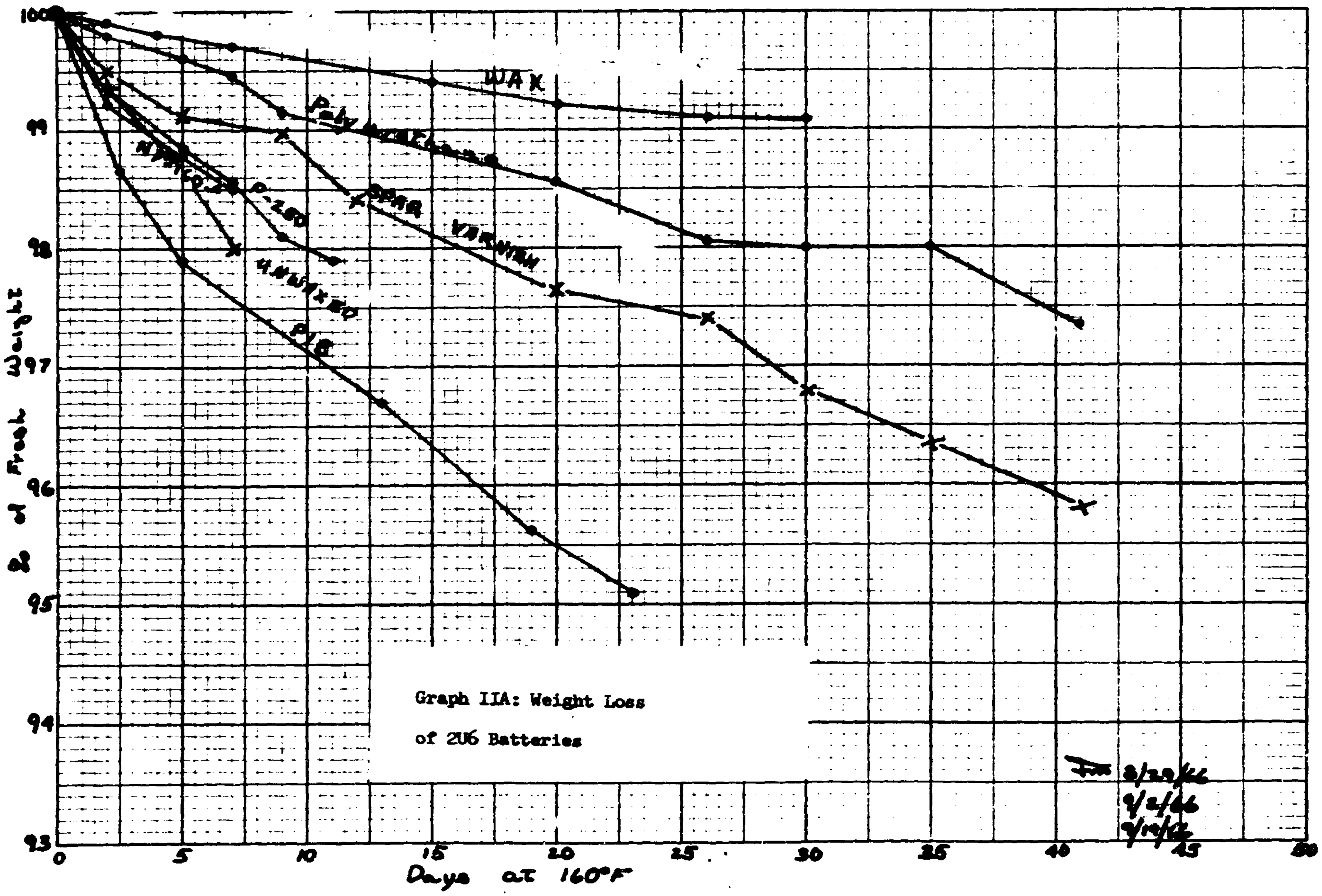
Drain,* Storage at 70°F and 160°F

Lot	Fresh OCV	Fresh Flash	1 Mon. 160°F OCV	1 Mon. 160°F Flash	1 Mon. 70°F OCV	1 Mon. 70°F Flash	Capacity to 1.0/.9 V. 1 Mon. 70°F	Capacity To 1.0/.9V 1 Mon. 160°F
1	1.60	3.0+	1.54	2.4	--	--	--	19.2/23.7
1	1.54	2.5	1.54	3.8	--	--	--	26.8/31.3
1	1.58	2.5	1.54	2.4	--	--	--	20.2/25.8
1	1.62	3.0+	1.54	4.2	--	--	--	31.4/34.9
2	1.56	2.5	1.54	3.2	--	--	--	20.8/25.8
2	1.60	3.0+	1.54	2.0	--	--	--	19.4/24.0
2	1.60	3.0+	1.55	2.2	--	--	--	13.3/28.0
2	--	--	1.55	2.0	--	--	--	18.7/23.3
3	Target	--	--	--	1.59	4.2	29.3/32.3	--
3	Similar	--	--	--	1.59	4.0	29.4/32.6	--
3	to lots	--	--	--	1.59	3.4	25.0/29.0	--
3	1 and 2	--	--	--	1.59	4.4	31.2/34.0	--
4	1.60	1.1	--	--	1.62	2.1	39.9/45.0	--
4	1.63	1.5	--	--	1.62	1.4	32.3/41.0	--
4	1.67	1.4	--	--	1.62	2.0	39.2/44.5	--
4	1.60	1.5	--	--	1.62	2.8	39.7/45.1	--
5	Target	--	--	--	1.62	2.2	38.1/42.4	--
5	Similar	--	--	--	1.62	1.8	38.8/43.3	--
5	to lot	--	--	--	1.62	2.3	38.0/41.3	--
5	4	--	--	--	1.62	2.2	38.7/42.6	--

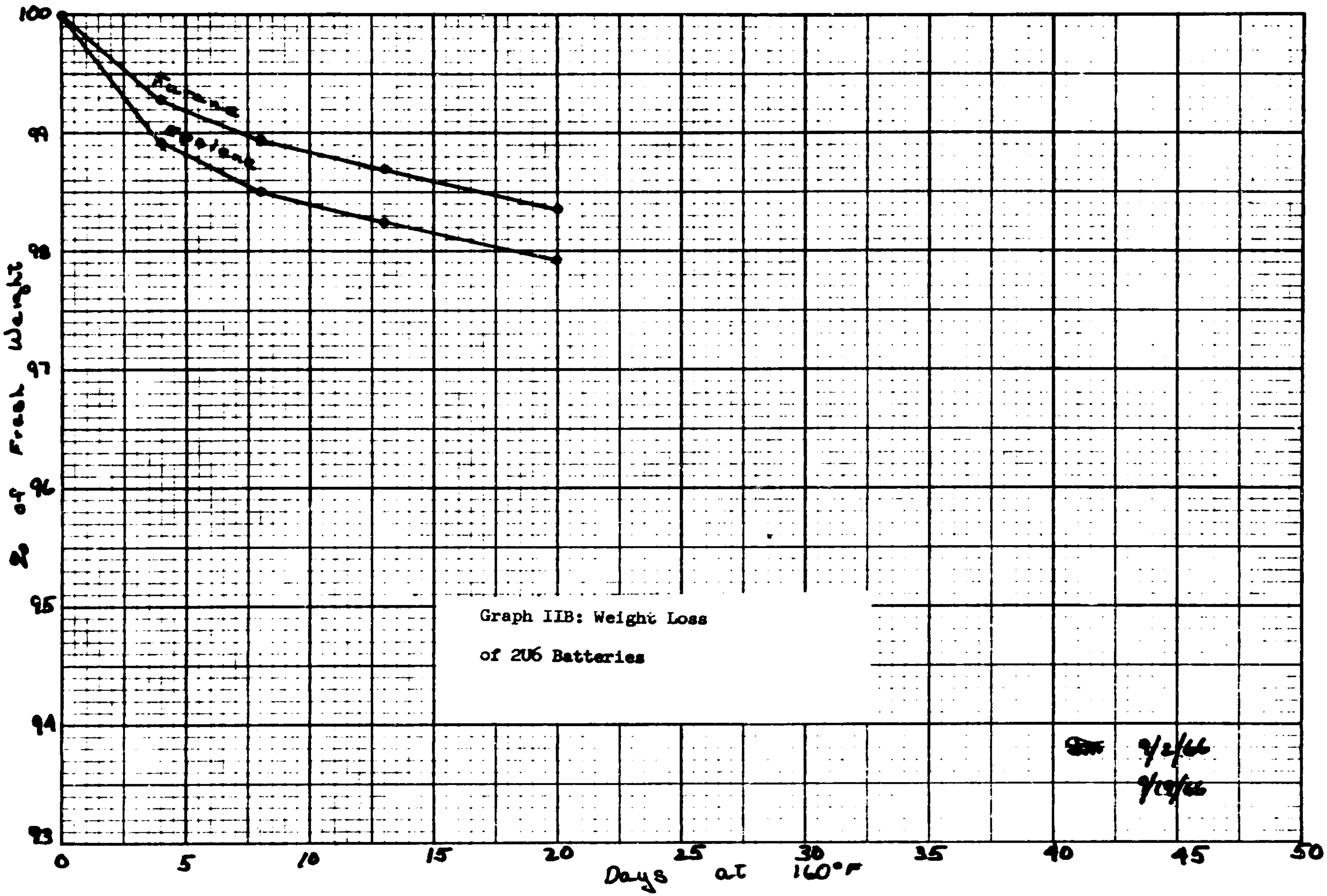
*Cells were drained on a load of 8.5 ohms for two minutes and then 176 ohms for 18 minutes to an end point of 1.0/.9 volts.



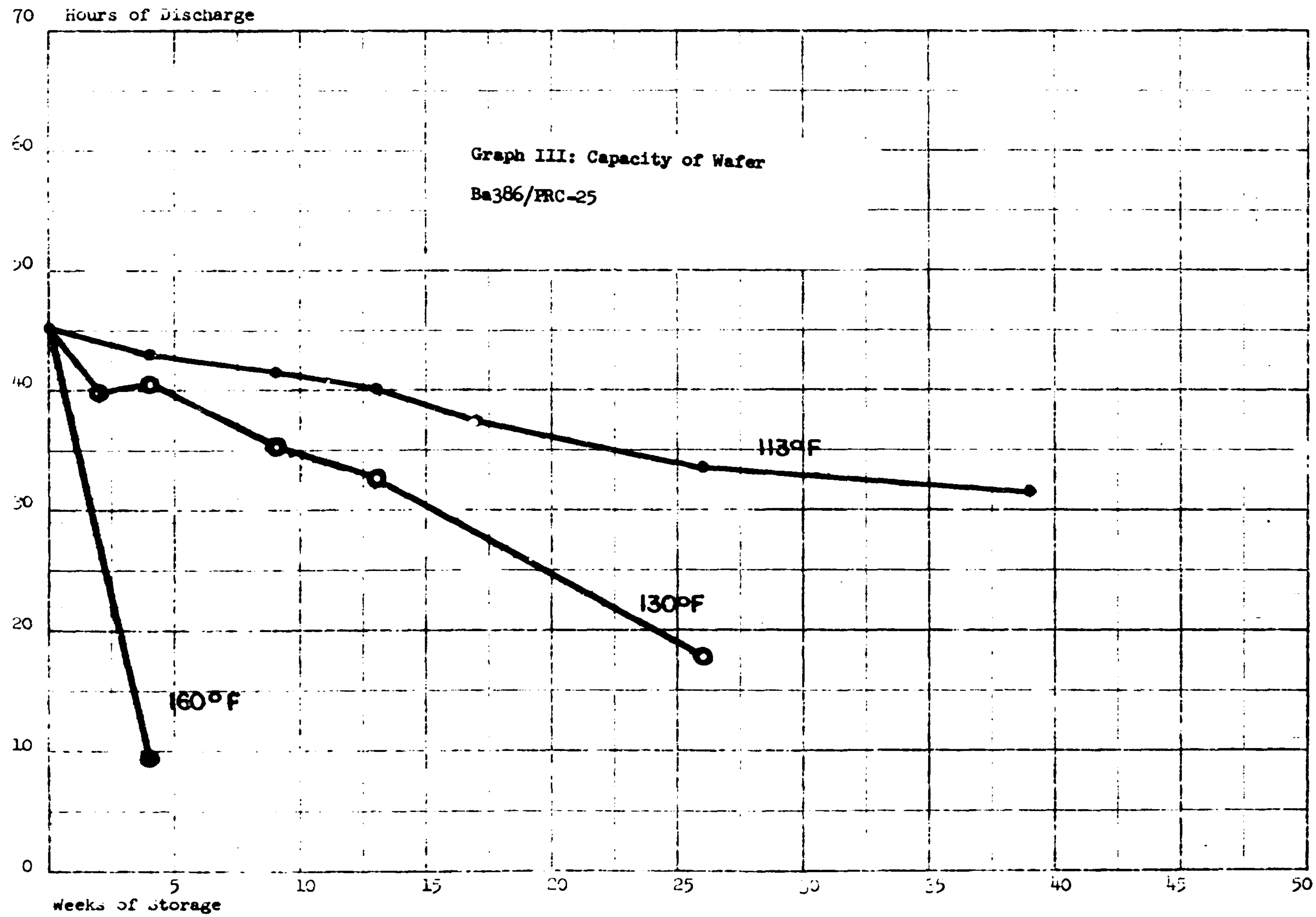
Hours of Discharge
70
60
50
40
30
20
10
0
Graph I: Capacity of Production
Spun Paste Ba386/PRC-25
70°F
113°F
130°F
145°F
160°F
5
10
15
20
25
30
35
40
45
50
Weeks of Storage

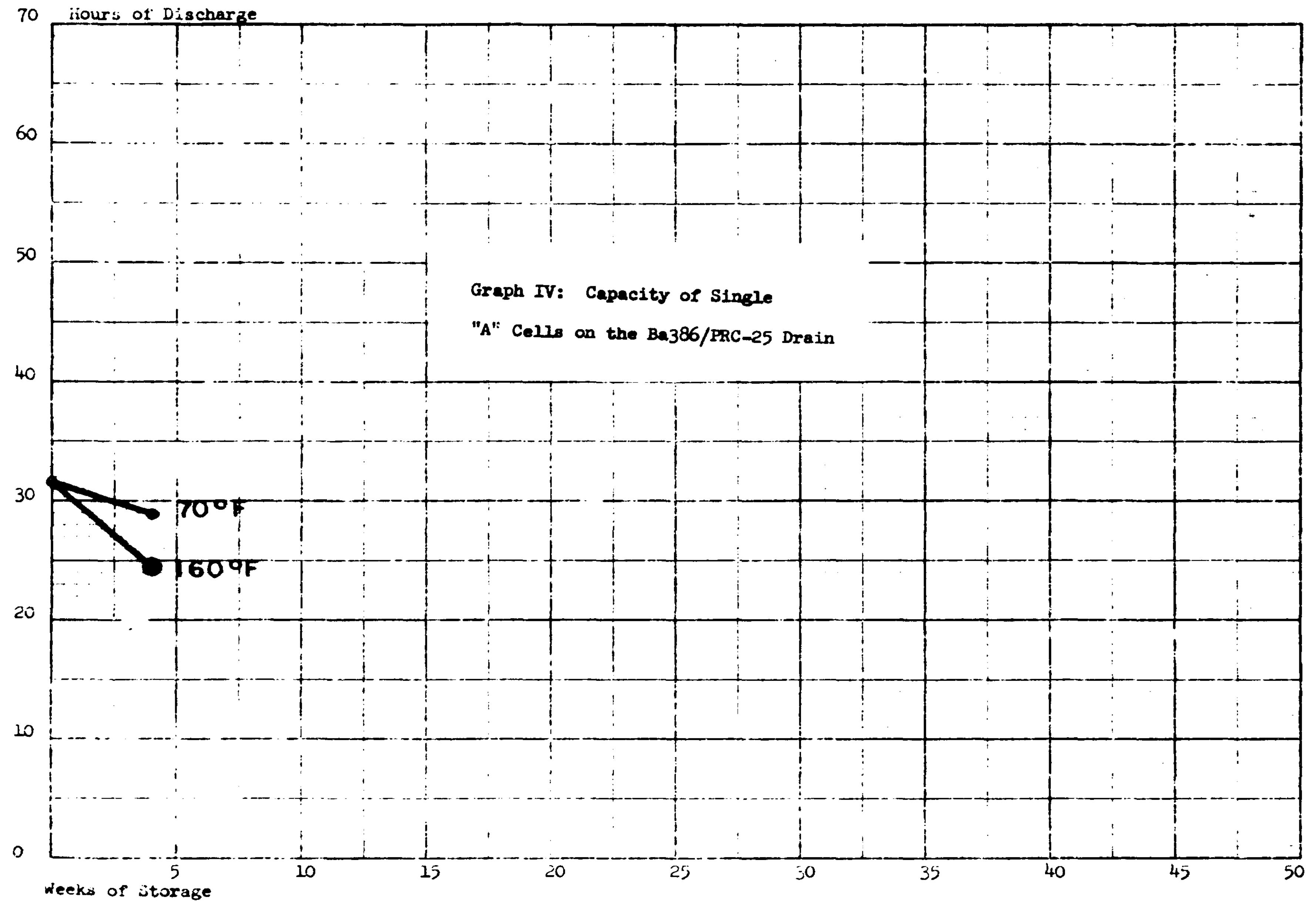


Graph IIA: Weight Loss of 2U6 Batteries



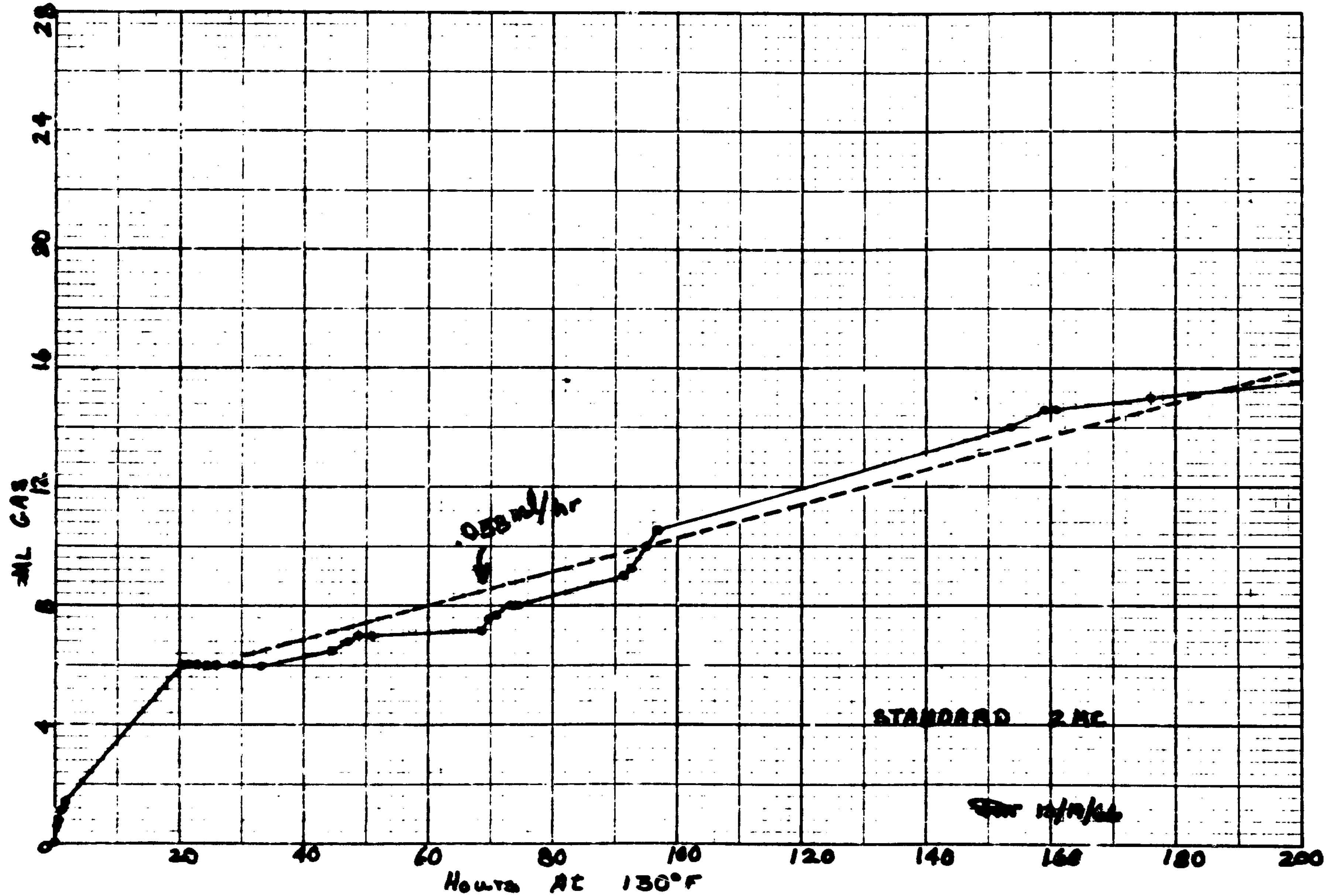
Graph IIB: Weight Loss of 2U6 Batteries


Hours of Discharge
70
60
50
40
30
20
10
0
Graph III: Capacity of Wafer
Ba386/PRC-25
113°F
130°F
160°F
5
10
15
20
25
30
35
40
45
50
Weeks of Storage



Graph IV: Capacity of Single "A" Cells on the Ba386/PRC-25 Drain

Graph V
Gassing of Control 2MC



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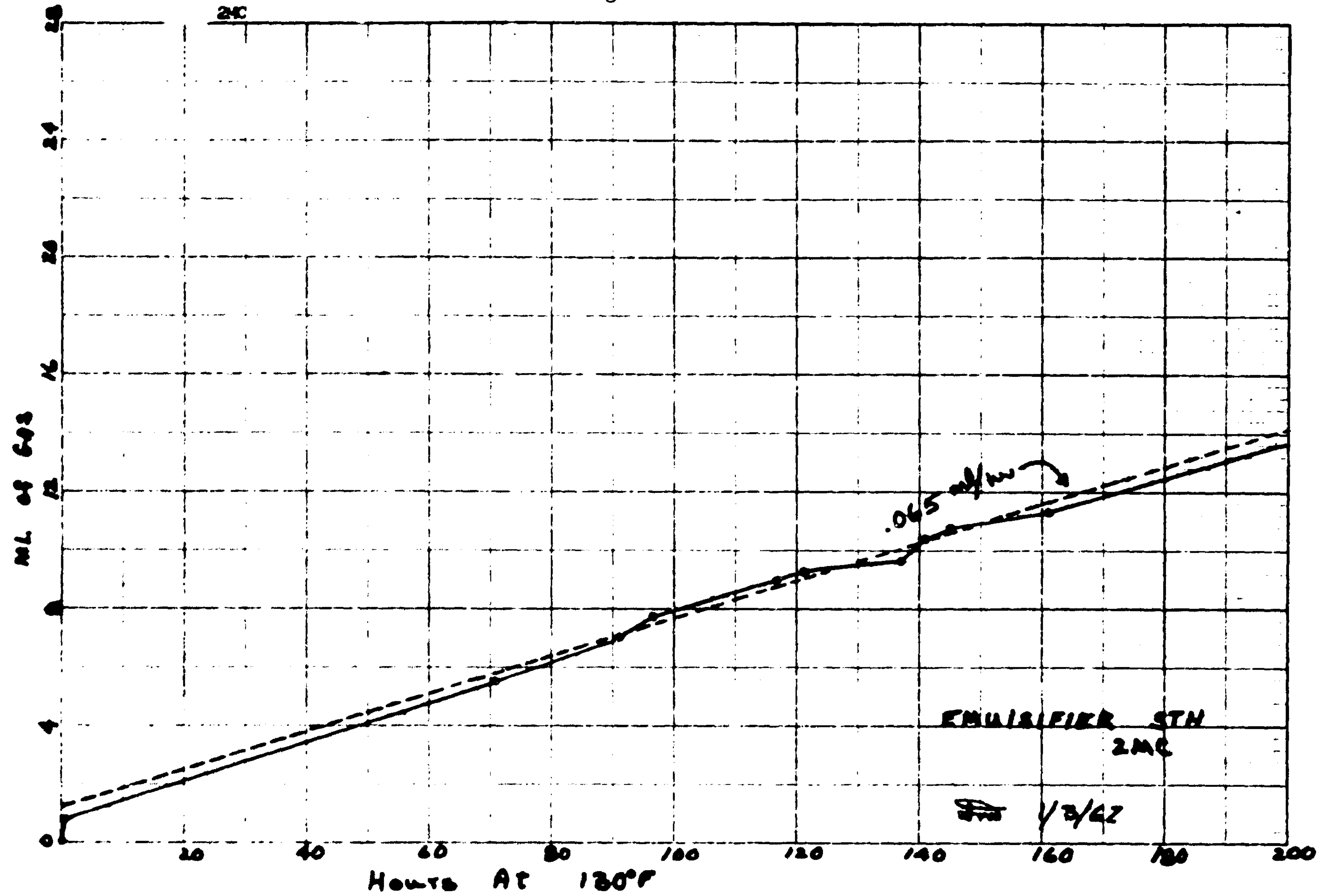
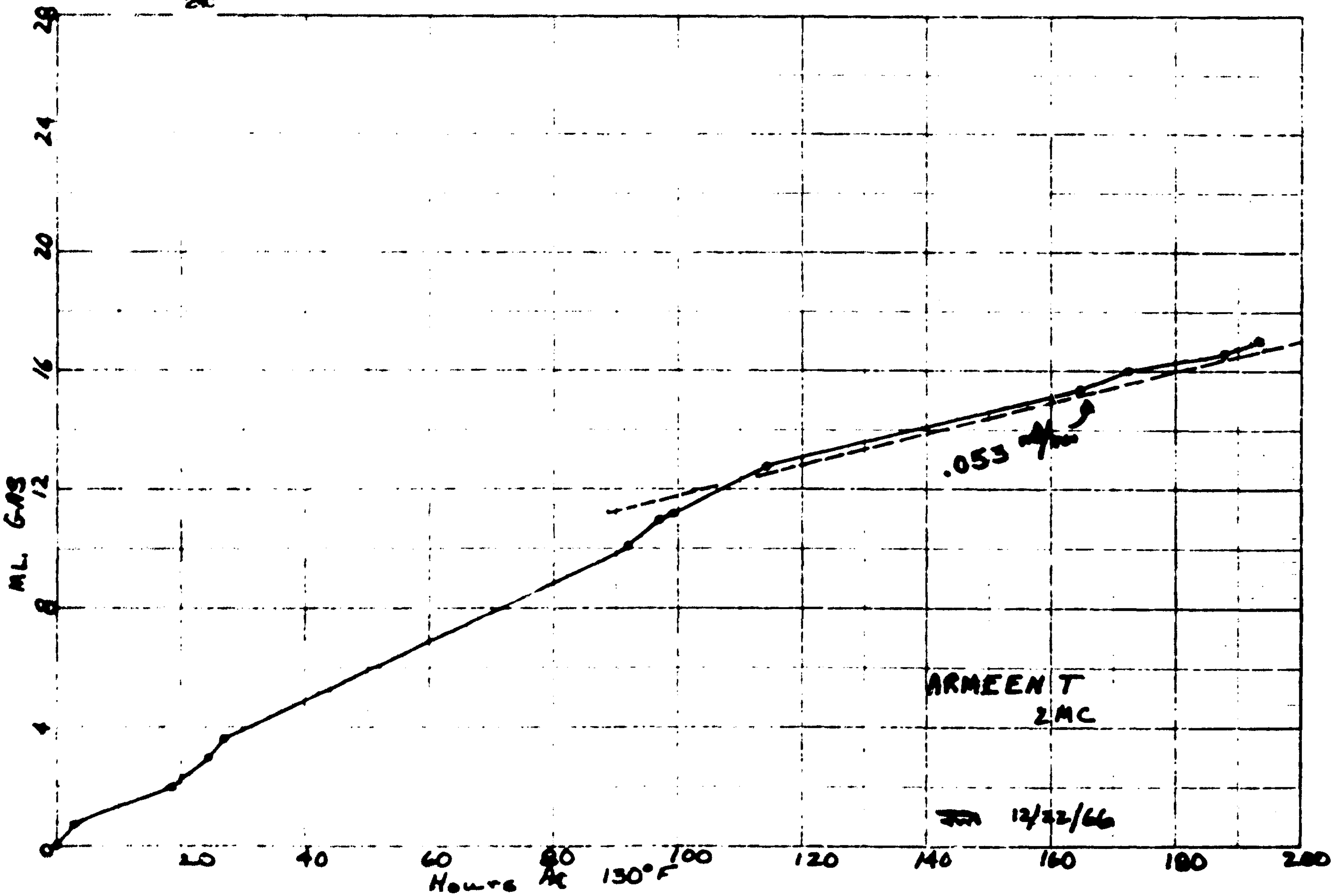
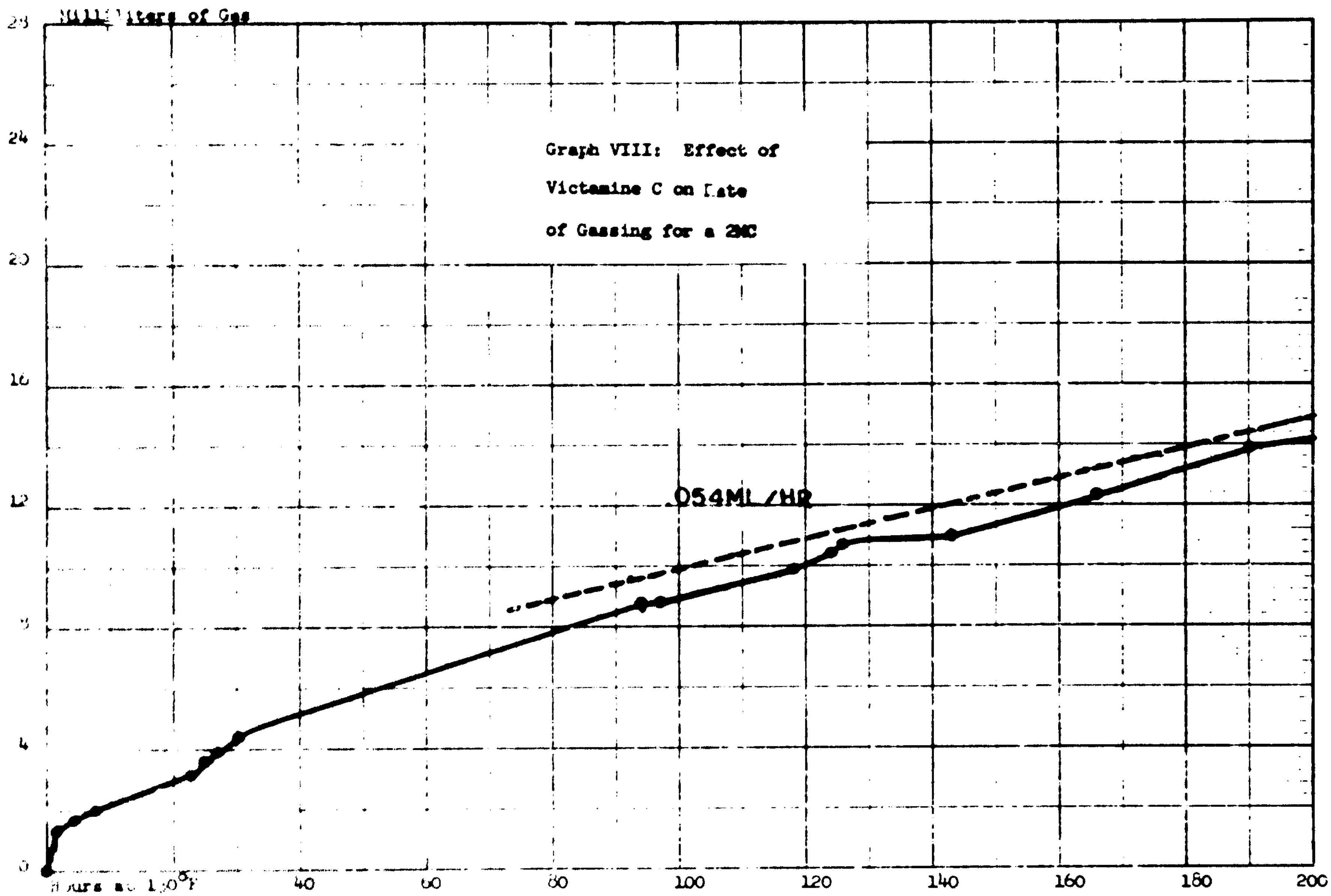
Graph VI
Effect of Emulsifier STH on Rate of Gassing
2MC

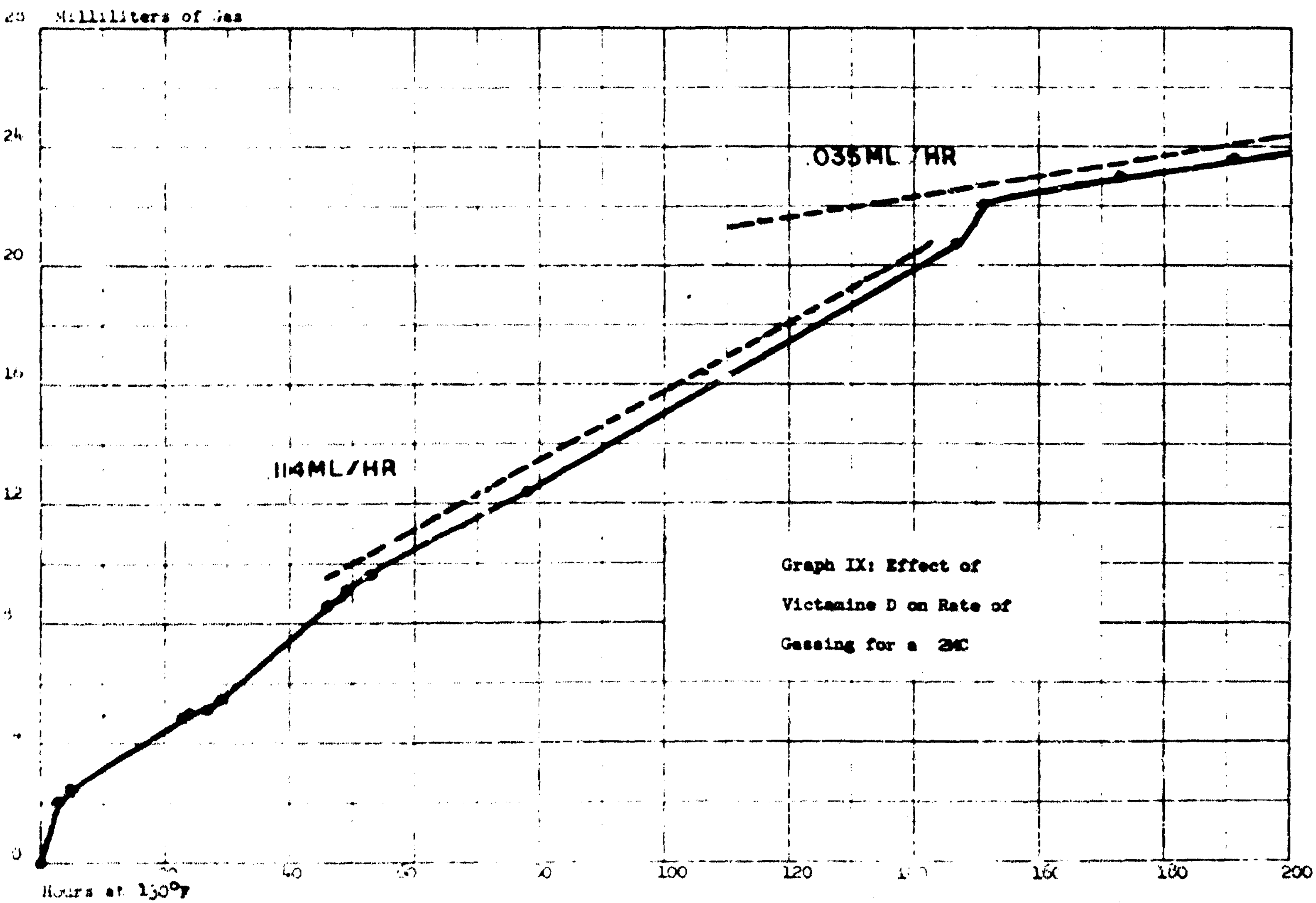


Graph VII
Effect of Armeen T on Rate of Gassing
2MC

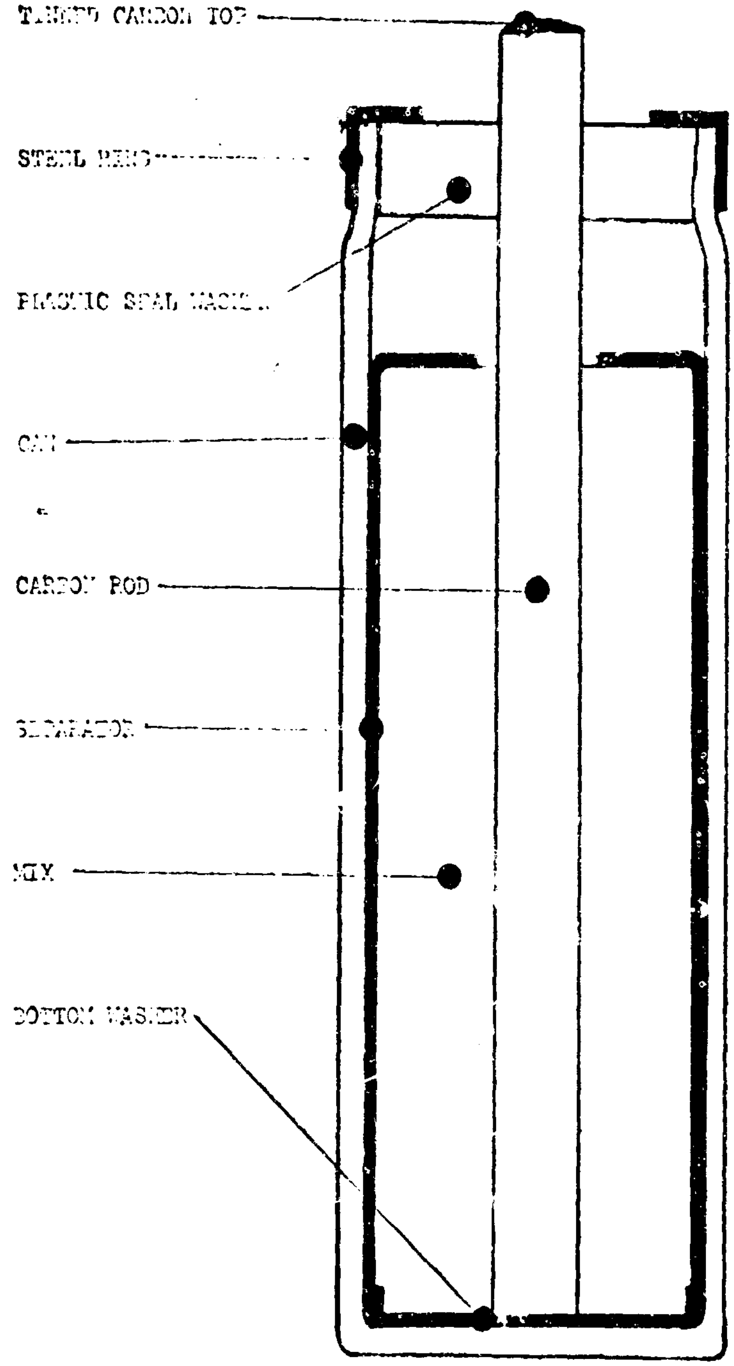




Graph VIII: Effect of Victamine C on Rate of Gassing for a 2MC



Graph IX: Effect of Victamine D on Rate of Gassing for a 2MC



BURGESS BATTERY COMPANY
FREEPORT, ILLINOIS

TITLE Figure 1
Mechanically Sealed Cell

DRAWN BY	REVISED	
CHECKED	APPROVED	
SCALE None	ISSUE	
DATE	DRG. NO.	

UNLESS OTHERWISE SPECIFIED--Inner Box Dimensions ± 1/64"--Wire Length ± 1/8"--All other Dimensions ± 1/32"

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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Final Report July 1966-March 1967

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13. ABSTRACT

Discussion of the development of a carbon zinc battery capable of prolonged storage at high temperatures is given. A summary of the ability of the present product is submitted. An analysis of the merits of geometric considerations is given, and data presented to show the capabilities of various cell constructions.

DD FORM 1 JAN 64 1473

Security Classification

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Primary Cells		1				
Carbon Zinc Batteries		4				
Carbon Zinc Round Cell Batteries		4				
Carbon Zinc Wafer Cell Batteries		4				

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